This document is guaranteed to be current only to issue date.

Some Mars Global Surveyor documents that relate to flight operations are under revision to accommodate the recently modified mission plan.

Documents that describe the attributes of the MGS spacecraft are generally up-to-date.

Mars Global Surveyor Project

Mission Requirements Document

September 1995

JPL

Jet Propulsion Laboratory
California Institute of Technology

JPL D-11956, Update

542-400

Mars Global Surveyor Project

Mission Requirements Document

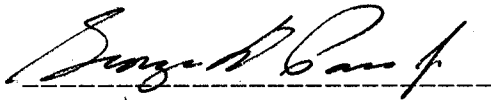Concurring:

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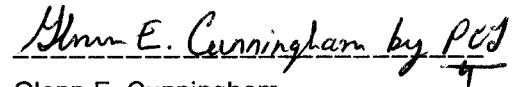
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September 1995

JPL

Jet Propulsion Laboratory
California Institute of Technology

JPL D-11956

TABLE OF CONTENTS

SECTION 4 TRACKING AND DATA ACQUISITION (TDA) SYSTEM REQUIREMENTS

SECTION 5 LAUNCH SYSTEM REQUIREMENTS

SECTION 6 SPACECRAFT SYSTEM REQUIREMENTS

SECTION 7   SCIENCE SYSTEM REQUIREMENTS

SECTION 8   MULTIMISSION GROUND SYSTEM OFFICE (MGSO) SYSTEM REQUIREMENTS

SECTION 9   REQUIREMENTS ON JPL SPACE COUNCIL

SECTION 10   REQUIREMENTS TRACEABILITY AND RATIONALE

TABLES AND FIGURES

SECTION 1 INTRODUCTION

1.1   PURPOSE/SCOPE

The Mars Global Surveyor Mission Requirements Document (MRD) documents the requirements for the Mars Global Surveyor mission and the resulting mission requirements upon the systems comprising the Mars Global Surveyor project. The requirements specified in this document are valid during the pre-launch development phase, post-launch mission operations, and data analysis phases of the mission.

1.2   RELATIONSHIP TO OTHER DOCUMENTS

The MRD shall be consistent with and responsive to the following documents:

Project Plan	542-100
Project Policies	542-110
Planetary Protection Provisions for Robotic Extraterrestrial Missions	NASA NHB 80201.12B

The Investigation Description and Science Requirements Document (542-300) and the MRD (542-400) are on the same level in the document organization.

The following documents shall be consistent with and responsive to the MRD:

Launch Vehicle System Requirements	542-18
Spacecraft Requirements	542-200
Planetary Protection Plan	542-402
Mission Plan	542-405
Navigation Plan	542-406
Mission Operations Specification	542-409
Trajectory Characteristics Document	542-410
Mission Requirements Request	542-422

1.3   DOCUMENT REFERENCES

1) Consultative Committee for Space Data Standards (CCSDS)

Telemetry - Summary of Concept and Rationale	CCSDS 100.0-G-1
Telemetry Channel Coding	CCSDS 101.0-B-1
Packet Telemetry	CCSDS 102.0-B-3
Telecommand - Summary of Concept and Rationale	CCSDS 200.0-G-6
Telecommand- Part 1- Channel Service	CCSDS 201.0-B-1
Telecommand- Part 2- Data Routing Service	CCSDS 202.0-B-2
Telecommand- Part 2.1- Command Operations Procedures	CCSDS 202.1-B-1
Telecommand- Part 3- Data Management Service	CCSDS 203.0-B-1

2) Spacecraft Clock	JPL-D-1672
3) Payload Data System Interface Requirements Document	JPL-D-4130
4) Payload Data System Functional Requirements Document	JPL-D-3419
5) DSN Capabilities	810-5 Rev D
6) Multimission Ground Systems Office User's Guide	MGSO 20-01

1.4   CHANGE CONTROL

Changes to the MRD shall be controlled using procedures set forth in the Project Configuration Management Plan (542-140).

1.5   DOCUMENT ORGANIZATION

Section 2 provides a description of the mission, including the project and science objectives. The definitions of the Project systems to which the requirements in this document are levied upon are also defined in Section 2. Section 3 documents the requirements on the mission system, while Sections 4-9 document the mission system requirements levied on the other Project systems. Section 10 documents the traceability and rationale for all the requirements contained in the previous sections.

SECTION 2 MISSION DESCRIPTION

This section provides a brief description of the Mars Global Surveyor mission.   The project and science objectives as defined in the Project Plan (542-100) are listed for reference. Additionally, the mission phases are defined. Finally, the project systems responsible for meeting the mission requirements listed in the following sections are defined.

2.1   MISSION DEFINITION

The Mission is defined as the utilization of the Project Systems in a manner consistent with the available resources and physical constraints and performance limitations to meet the Project Objectives.

2.2   PROJECT OBJECTIVES

The Project Objectives, listed in the MGS Project Plan (542-100) are included here for completeness.

1) Complete, as fully as possible, the original science objectives of the Mars Observer mission.

2) Provide multiple years of on-orbit relay communications capability for future Mars landers and atmospheric vehicles, in support of the International Mars Exploration Program.

3) Support planning for future Mars missions through data acquisitions with special emphasis on those measurements which could impact landing site selection.

2.3   SCIENCE OBJECTIVES

The Science Objectives, summarized in the MGS Project Plan (542-100) are included here for completeness.

1) Characterize surface morphology at high spatial resolution to quantify surface characteristics and geological processes.

2) Determine the composition, map the distribution, and measure the surface thermo-physical properties of surface minerals, rocks, and ices.

3) Determine globally the topography, geodetic figure, and gravitational field.

4) Establish the nature of the magnetic field and map the crustal remnant field.

5) Monitor global weather and thermal structure of the atmosphere.

6) Study surface-atmosphere interaction by monitoring surface features, polar caps, polar thermal balance, atmospheric dust, and clouds over a seasonal cycle.

2.4   MISSION DESCRIPTION

The Mars Global Surveyor mission will deliver a single spacecraft to Mars for an

extended orbital study of the planet's surface, atmosphere, and gravitational and magnetic fields. Launch will occur during the November 1996 Mars opportunity by a Delta II 7925 launch vehicle, with a flight time of just over 10 months. During the cruise period, a series of small trajectory correction maneuvers (TCMs) will be performed to remove planetary protection injection biasing of the upper stage, correct trajectory dispersions introduced by the upper stage during injection, and control the approach trajectory to Mars for planetary protection purposes. Upon arrival at Mars in September 1997, the spacecraft will be inserted into an initial highly elliptic capture orbit. Over the next few months, the spacecraft will be lowered to the desired mapping orbit by utilizing aerobraking methods. Transition into the mapping orbit is expected by March 1998. After achieving mapping orbit, repetitive observations of the planet's surface and atmosphere will be conducted over the primary mission which extends for 687 days (one Martian year). Mars Global Surveyor will support the International Mars Exploration Program by relaying data from various landers and atmospheric vehicles for a three year period following the completion of the mapping mission.

2.4.1 Mission Phase Definitions

Launch Phase

The launch phase extends from the start of the launch countdown to separation of the spacecraft from the Delta third stage.

Cruise Phase

The cruise phase extends from spacecraft separation to the initiation of the Mars Orbit Insertion (MOI) maneuver. It includes initial checkout of the spacecraft, and the required trajectory correction maneuvers (TCMs) and calibrations.

Orbit Insertion Phase

The orbit insertion phase extends from initiation of MOI until the spacecraft is declared ready to collect mapping phase science data. During this phase, the insertion into the mapping orbit will be accomplished, and the spacecraft configured to commence science data collection.

Mapping Phase

Mapping phase duration is 687 Earth days (one Martian year), initiating when mapping readiness is declared. During this phase the spacecraft is collecting science data from the Mars mapping orbit.

Relay Phase

Relay phase extends from the end of the mapping phase for the remainder of the spacecraft five Earth-year on-orbit design life, approximately from early 2000 through January 2003. During this phase, the spacecraft shall function primarily as a relay satellite in support of the International Mars Exploration Program.

2.5   PROJECT SYSTEM DEFINITIONS

The following project systems are defined for the purpose of categorizing the requirements. These definitions are consistent with the definitions in the Project Plan (542-100).

2.5.1   Project Funded Systems

Mission System

The mission system consists of the organizational elements required to design the mission and to develop and conduct flight operations. During the development phase (design and implementation), the Mission System is divided into three elements: mission design, navigation design, and mission operations design and implementation. With completion of the development phase, these elements are merged into a single operations organization. The operation organization is supported by two institutionally funded capabilities described in Paragraph 2.5.2.

Science System

The science system consists of the payload and the science investigations. The payload is defined to be the complement of the science instruments, which include the Magnetometer / Electron Reflectometer (MAG/ER), Mars Observer Camera (MOC), Mars Observer Laser Altimeter (MOLA), Thermal Emissions Spectrometer (TES), the Ultra Stable Oscillator (USO) for radio science, and the Mars Relay (MR).

Spacecraft System

The Spacecraft Manager administers a contract with Lockheed Martin Astronautics (LMA) in Denver, Colorado to design and fabricate the spacecraft bus, integrate the payload, support integration of the spacecraft with the launch vehicle, and support mission design and mission operations. The spacecraft system is a composite of the spacecraft bus and the payload, as defined above, after integration. The spacecraft bus comprises all assemblies, engineering subsystems, associated flight software, and miscellaneous hardware that constitute the spacecraft without the science instruments. Additionally, the spacecraft bus includes the necessary adapter for interfacing with the Launch vehicle.

2.5.2   Institutionally Funded Capabilities

Multimission Operations Support Office

The Multimission Ground System Office (MGSO) provides computer hardware, software, operations personnel, and facilities for supporting flight operations.

Telecommunications and Data Acquisition

The Office of Telecommunications and Data Acquisition (TDA) provides the capabilities of the Deep Space Network (DSN) to support the mission. TDA arranges for access to and use of the hardware, software, resources for computer operations, and operations personnel of the Network Operations Center (NOC).

2.5.3   Launch System

The launch system consists of the Delta II 7925 launch vehicle and the personnel, test equipment, and facilities at the Kennedy Space Center (KSC) and the Cape Canaveral Air Force Station (CCAFS) for preparation, integration and launch of the spacecraft and launch vehicle. The Delta II 7925 launch vehicle configuration consists of a solid motor augmented first stage, a liquid propulsion restartable second stage and a spin-stabilized solid propulsion third stage (PAM-D), and payload fairing.

SECTION 3 MISSION DESIGN REQUIREMENTS

This section documents the requirements on the three elements of the mission system, consisting of mission design, navigation design and mission operations design.

3.1 REQUIREMENTS ON MISSION DESIGN

3.1.1 Launch Opportunity

Launch shall occur during the 1996 Mars opportunity from the Cape Canaveral Air Station (CCAS), with a probability of 0.99.

3.1.2 Launch Vehicle

The launch vehicle shall be the Delta II 7925.

3.1.3 Launch Period

A launch period of 21 consecutive days shall be defined to initiate an Earth-Mars trajectory. Two launch opportunities per day shall be planned for at least the first half of the launch period. The daily launch time separation shall satisfy launch operations constraints.

3.1.4 NASA Planetary Protection

The mission design shall ensure that the probability of accidental impact of the launch vehicle upper stage on Mars shall be less than 10^{-5}. The mission design shall also ensure that the probability of accidental impact of the spacecraft on Mars shall be less than 10^{-2} up to 20 years after launch and 0.05 for an additional 30 years. At the end of the mission, if necessary, the orbit of the spacecraft shall be raised to a quarantine altitude that will satisfy the above requirements.

3.1.5 Cruise and Orbit Insertion Phase Science

Science activity during the cruise and orbit insertion phases shall be planned pre-launch and be consistent with the inherent capabilities of the spacecraft and with a policy of minimizing complexity, risk, and resource utilization in mission operations. First priority shall be given to essential instrument calibrations which cannot be performed during the mapping phase.

3.1.5.1 Payload Engineering Checkout

The mission design shall provide a payload engineering checkout of the TES, MOC, MOLA, MAG, and MR instruments between Launch + 18 days and Launch + 30 days. Duration is approximately 10 days. Three DSN passes per day shall support the checkout. The checkout shall include spacecraft reorientations to capture star images for the MOC focus test.

3.1.5.2 MOC Post-Bakeout Focus Check

The mission design shall provide for collection of star images for the MOC post-bakeout focus check.

3.1.5.3   MAG Calibration

The mission design shall provide for MAG calibrations with spacecraft roll turns if the spacecraft magnetic field cannot be characterized during pre-flight integration and test.

3.1.5.4   MOC Pre-MOI Mars Approach Observations

The mission design shall provide for periodic operation of the MOC during the approach to Mars. Specific maneuvers to orient the spacecraft to observe the planet and bright stars may be required. Observing periods approximately every thirty days from MOI - 120 days until approximately MOI - 20 days (not to interfere with TCM-4).

3.1.5.5   Science Observations During the Orbit Insertion Phase

Magnetometer and gravity science (tracking) data shall be collected throughout the orbit insertion phase. MOC, MOLA and TES data shall be collected from at least two nadir oriented periapsis passes during the capture orbit. MOC and TES data shall be collected during post drag pass planet scans in walkin and early mainphase when the orbit period is greater than 10 hours. TES observations of Mars and Phobos shall be performed in the nominal cruise attitude during the capture orbit and during early mainphase. In early mainphase, TES shall collect data during the drag passes. While in the capture orbit, Mars 96 lander relay support shall be provided with special spacecraft attitudes during periods outside of the periapsis pass.

3.1.5.6   MOC Star Images Before Mapping Deployment

The mission design shall provide for the collection of MOC star images after the TMO maneuver and before OTM-1.

3.1.6   Mapping Orbit Design

The mapping orbit shall be sun synchronous with a day side node located at 2:00 pm local mean solar time. The orbit semi-major axis shall be 3775.1 km to provide a 7-sol repeat cycle. The orbit design shall provide a repeating ground track pattern which permits full coverage of the surface except at the poles. A frozen orbit design shall be used. Table 3-1 defines the complete set of mapping orbit mean elements.

Table 3-1   Mapping Orbit Mean Elements (averaged over one orbit)

Orbit Element[1]	Mean Value and Bounds
Semi-major Axis, km	3775.1 +0.7/-1.2
Eccentricity	0.0072 ± 0.007
Inclination, deg	92.87
Ascending Node, deg[2]	$-39.1664 + 0.524T \pm 3$
Argument of Periapsis, deg	-90 ± 10
Mean Anomaly, deg	Arbitrary

[1]   The coordinate system is the Mars equator and International Astronomical Union (IAU) vector of epoch.

[2]   T is Earth days past January 1, 1998 at 0000 hours ET.
      The ascending node is located on the night side of the planet.

3.1.7   Gravity Calibration Period

The mission design shall provide for a period of uniform planet coverage in a low orbit, prior to the start of mapping phase, during which a gravity calibration data set is obtained.

3.1.8   Spacecraft and Instrument Checkout Period

The mission design shall provide a spacecraft and instrument checkout period not exceeding 10 days after entering the mapping orbit and before commencement of the mapping phase.

3.1.9   Mapping Phase Commencement

The mapping phase shall commence no later than 10 days upon achieving the final mapping orbit.

3.1.10   Mapping Phase

The mission design shall allow science observations to be conducted for 687 days from commencement of the mapping phase.

3.1.11   Relay Phase

Upon completion of the mapping phase, the mission design shall support an approximate three year relay phase, during which the spacecraft will support the return of data from landers as part of the International Mars Exploration Program. The relay orbit design shall be compatible with the spacecraft configuration and resources and be consistent with Planetary Protection requirements.

3.1.12   Science Data Return

There shall be two approaches for returning science data during the mapping phase: playback of recorded data and real-time data. Continuous science data collection, except during solar conjunction periods, shall be provided by recording data on the spacecraft and transmitting it to the ground during a daily 34-m (HEF) tracking pass.

To permit the return of high rate real-time data from the science payload, real-time data collection shall be planned during the additional tracking coverage, scheduled for one tracking pass approximately every third day.

3.1.13   Radio Science Data Acquisition

The mission design shall provide for the acquisition of radio science data, in the mapping phase, for all Earth occultations per day that occur in the view of the scheduled DSN station.

3.1.14   Solar Conjunction Command Moratorium

During the two-week periods centered around the three solar conjunctions in the mapping and relay phases, spacecraft commanding will be impaired by the proximity of the Sun to the radio transmission path (Sun-Earth-Mars angle less than 2 degrees). The mission design shall not require spacecraft commanding during these conjunction periods, centered at May 13, 1998,

July 2, 2000, and August 11, 2002. The mission design shall not require maneuvers within 2 days of each period.

3.1.15   DSN Usage

The mission design shall require data acquisition through most of the mission to be planned for one tracking pass per day through a 34-m high efficiency (HEF) antenna of the DSN.

During the cruise and orbit insertion phases, mission design shall plan additional tracking passes to provide essential navigation data and coverage of critical activities such as maneuvers and orbit insertion.

During the mapping phase, mission design shall plan additional tracking coverage to permit the return of high-rate real-time science data, approximately every third day. The mapping phase shall also include science campaigns as noted in Table 3-2. Each campaign shall require continuous DSN coverage for a 7-day period.

Table 3-2 lists the required DSN coverage for the mission.

TABLE 3-2   DSN COVERAGE REQUIREMENTS

L to L + 30 days:

Continuous coverage through the 34m HEF subnet. Acquire tracking data as soon as possible after launch. This period will include the first TCM at L+15 days.

Nav Data: 2-way coherent Doppler and ranging. Angular data from L to L+1 day.

L + 30 days to MOI - 90 days:

One pass per day through the 34m HEF subnet with typical pass duration of 10 hours.

Nav Data: 2-way coherent Doppler, 3-way Doppler and ranging.

Continuous coverage through the 34m HEF subnet from 3 days before to 3 days after each TCM. For the first launch date (November 5, 1996), TCM-1 is scheduled for November 20, 1996, TCM-2 for March 20, 1997, TCM-3 for April 20, 1997, and TCM-4 for August 22, 1997.

Nav Data: 2-way coherent Doppler and ranging.

MOI - 90 days to MOI - 30 days:

Two passes per day through the 34m HEF subnet with typical pass duration of 10 hours.

Nav Data: 2-way coherent Doppler and ranging.

MOI - 30 days to Beginning of Mapping (~7 months):

Continuous coverage through the 34m HEF subnet. Continuous 70m coverage from MOI-24 hours to MOI+24 hours.

Nav Data: 2-way coherent Doppler, 3-way Doppler (34m only) and ranging.

Beginning of Mapping to Beginning of Communications Relay Mission (~2 years):

One pass per day through the 34m HEF subnet with typical pass duration of 10 hours for playback of recorded data. An additional pass nominally every third day through the 34m HEF for return of real-time data.

Nav Data: 2-way coherent Doppler, 3-way Doppler and ranging.

Radio Science Data: open loop recording during atmospheric occultations, other wise 2-way coherent doppler and ranging

Note: A 34m BWG or 70m station with comparable uplink/downlink performance, can be substituted as negotiated with the project.

TABLE 3-2   DSN COVERAGE REQUIREMENTS (Continued)

For a 28 day period centered on the 10/30/98 and 2/19/99 (edge-on orbital configuration), one additional 10 hour 34m HEF pass per day with a 2-4 hour overlap with the daily tracking pass.

Nav Data: During the overlap, simultaneous 2-way coherent Doppler and 3-way Doppler.

Radio Science Data: open loop recording during atmospheric occultations, other wise 2-way coherent doppler and ranging

Science Campaigns in Mapping Phase

Gravity Campaigns require continuous coverage through the 34m HEF subnet for three 7-day periods in October 1998, May 1999 and September 1999.

Nav Data: 2-way coherent Doppler, 3-way Doppler and ranging.

Radio Science Data: open loop recording during atmospheric occultations, other wise 2-way coherent doppler and ranging

Diametric Earth Occultations

During periods when the spacecraft ground track corresponds with that of the radio signal to Earth and Radio Science (RS) and the Thermal Emission Spectrometer (TES) can view the Mars atmosphere through the same air mass, DSN coverage is required for 12 hours before and after the time of the diametric Earth occultation.

Radio Science Data: open loop recording during atmospheric occultations, other wise 2-way coherent doppler and ranging

Geodesy Campaigns

During four 7 day periods (only three such periods are needed if the 80 Ksps real-time rate is used) when the Mars atmosphere is expected to be reasonably clear (such a period is expected to occur in early 1999) continuous tracking and real-time data return is required. For each 7 day period real-time coverage is needed for 8 out of every 12 orbits. The orbit sets to be used and the time between 7 day periods will be adjusted from one 7 day period to the next to provide full planet coverage. If possible the four periods should be arranged so that the polar regions are illuminated in at least one of the four periods.

Note: A 34m BWG or 70m station with comparable uplink/downlink performance, can be substituted as negotiated with the project.

TABLE 3-2   DSN COVERAGE REQUIREMENTS (Continued)

Global Color Imaging

At about 6 month intervals real-time coverage is required to provide four consecutive passes to allow moderate resolution (1 to 1.75 Km/pixel), two color images of the illuminated portion of Mars to be obtained.

Atmosphere

Up to four 7 day periods of continuous DSN coverage are required for the purpose of obtaining concentrated observations of the atmosphere during periods of special interest (e.g. initiation of dust storms and winter storms, carbon dioxide ice clouds in the North and South polar regions, mid-spring water release, closing of the dust storm period, and water transport across the equatorial zone).

Beginning of Communications Relay Mission to End of Mission (3 years):

One pass per day through the 34m HEF subnet with typical pass duration of 10 hours.

Nav Data: 2-way coherent Doppler and ranging.

Note: A 34m BWG or 70m station with comparable uplink/downlink performance, can be substituted as negotiated with the project.

3.1.16   Maneuver Constraints

3.1.16.1   Trajectory Correction Maneuvers

The mission design shall not require a TCM before L +15 days or after MOI - 20 days.

3.1.16.2   Maneuver Interval

The mission design shall not require spacecraft propulsion maneuvers less than 10 days apart, except in the aerobraking phase. The mission design shall not require aerobraking maneuvers less than 24 hours apart.

3.1.16.3   Sun-safe Maneuver Direction

The mission design shall not require spacecraft propulsion maneuvers which place the spacecraft axis normal to the nadir panel within 30 degrees of the sun direction.

3.1.17   Aerobraking

The orbit insertion phase shall be designed to accommodate aerobraking maneuvers to reduce orbital energy.

3.1.18   Avoidance of Spacecraft Overheating During Capture

To avoid heating damage to the spacecraft, the mission design shall ensure that the altitude of the first Mars periapsis shall be greater than 150 km areographic altitude with probability 0.999, assuming a Mars equatorial radius (IAU, 1976) of 3397.2 km and Mars flattening of 1/158.

3.2 REQUIREMENTS ON NAVIGATION DESIGN

The requirements on navigation listed below which depend on the acquisition of tracking data are conditional requirements. Navigation is obligated to meet these requirements on the condition that the tracking coverage specified in Table 3-2 is achieved. Otherwise, Navigation will comply with these requirements on a best efforts basis.

3.2.1 Mission Delta–V Allocation

The navigation design shall meet the following translational delta–V allocations for the launch period opening trajectory (11/5/96). Allocations a), e) and f) shall be satisfied to at least a 95th percentile confidence. The other allocations are based on primarily deterministic velocity changes. As necessary, for other launch date trajectories, contingency delta-V can be reallocated to cover the nominal mission propulsive maneuvers.

a)	cruise TCMs, including injection aim point bias	52.9 m/s
b)	mars orbit insertion (MOI), including finite burn losses	975.6 m/s
c)	transition to mapping	119.3 m/s
d)	contingency	29.7 m/s
e)	mapping orbit maintenance and control	3.9 m/s *
f)	relay orbit maintenance	4.8 m/s *
g)	quarantine orbit maneuver	12.0 m/s
		1198.2 m/s **

* based on a nominal spacecraft ballistic coefficient of 20 kg/m^2.
** does not include 91.8 m/s delta-V for attitude control purposes (rotational delta-V)

The launch date with the largest translational delta–V requirement is the last day of the launch period. For this trajectory a minimum contingency delta-V of 17 m/s shall be maintained. The total delta-V (translational plus rotational) for this mission is 1290 m/s, including, contingency, finite burn losses, injection aim point bias for planetary protection, and attitude control.

3.2.2 Avoidance of Spacecraft Overheating During Capture

To avoid heating damage to the spacecraft, the altitude of the first Mars periapsis shall be greater than 150 km areographic altitude with probability 0.999, assuming a Mars equatorial radius (IAU, 1976) of 3397.2 km and Mars flattening of 1/158.

3.2.3 Planetary Protection

The navigation design shall ensure that the probability of accidental impact of the launch vehicle upper stage on Mars shall be less than 10^{-5}. The navigation design shall also ensure that the probability of accidental impact of the spacecraft on Mars shall be less than 10^{-2} up to 20 years after launch and 0.05 for an additional 30 years. At the end of mission, if necessary, the orbit of the spacecraft shall be raised to a quarantine altitude that will satisfy the above requirements.

3.2.4 Mapping Orbit Specification

Navigation shall establish the spacecraft in the mapping orbit specified in Table 3–1.

3.2.5   Mapping Orbit Maintenance

The mapping orbit shall be adjusted as necessary to satisfy the following bounds on orbital parameters.

3.2.5.1   Node

The ascending node shall be maintained within ±3 deg of the nominal location specified in Table 3–1.

3.2.5.2   Semi–Major Axis

The semi–major axis shall be maintained within +0.7/-1.2 km of the nominal value specified in Table 3-1.

3.2.5.3   Eccentricity

The upper bound of the frozen eccentricity shall be less than or equal to 0.014. If an upper bound of 0.013 is achieved, then the variation in the eccentricity must be within 0.001 in order to be within the allowable altitude variation.

3.2.6   Mapping Orbit Prediction – 14 Days

Nominally once a week, Navigation shall deposit into the project database an ephemeris of the spacecraft's position. Over a fourteen day interval (starting at the end of the tracking pass used in the prediction analysis), the spacecraft's position uncertainty is as follows (95% confidence for DT and three–sigma for CT and R). Worst case errors are given at perihelion as indicated. These results exclude solar conjunction.

Accuracy (3 ,km)

Position Component	Perihelion 1 (1/7/98)	Perihelion 2 (11/25/99)
Downtrack (DT)	20*	150*
Crosstrack (CT)	9	9
Radial (R)	8	8

*   DT errors are driven by the atmospheric density uncertainty; a 95% confidence level was used.

3.2.7   Orbit Reconstruction During Mapping Phase

Navigation shall reconstruct the actual flight path of the spacecraft to the following accuracies:

Position Component	Accuracy (3σ)
Downtrack (DT)	9 km
Crosstrack (CT)	5 km
Radial (R)	2 km

This requirement excludes the solar conjunction interval.

3.2.8   Aerobraking Maneuver Frequency

Navigation shall be capable of supporting aerobraking maneuvers, as frequently as once a day.

3.2.9   OTM Frequency

In meeting the mapping orbit maintenance requirements of Paragraph 3.2.5, Navigation shall not be required to perform orbit trim maneuvers (OTMs) more frequently than once a month.

3.2.10   Aerobraking Phase Orbital Accuracy

The time of periapsis passage shall be predicted to a 225 s accuracy consistent with a 70% atmosphere density change. The radius of periapsis shall be predicted to a 1.5 km accuracy consistent with the same density change. The prediction interval shall be consistent with the operations timelines for sequence and ephemeris updates.

3.2.11   Payload Sun Avoidance

The navigation design shall not require spacecraft propulsion maneuvers which place the spacecraft axis normal to the nadir panel within 30 degrees of the sun direction.

3.2.12   Relay Orbit Specification and Maintenance

Navigation shall establish the spacecraft in a relay orbit at the completion of the mapping phase. The relay orbit shall be maintained within the bounds of orbital parameters specified in Table 6-1 during the relay phase.

3.3   REQUIREMENTS ON MISSION OPERATIONS DESIGN

3.3.1   Institutional Support

Mission Operations shall use the multi-mission services of the institutional DSN and MGSO.

3.3.2   Data Acquisition

3.3.2.1   Data Constraints

Mission Operations shall select and maintain spacecraft operating modes for data acquisition and corresponding telecommunication return rates, based on:

(a)   attainment of a telecommunication link rate with a probability greater than 0.95

(b)   use of a High Efficiency (HEF) 34-meter station or equivalent, except when project activities and link conditions require a 70-meter or equivalent capability; and

(c)   constant science data record rate maintained throughout a 24 hour collection period.

3.3.2.2   DSN Constraints

Operations, tracking, command, and data return activities shall be based on DSN coverage requirements of Table 3-2.

3.3.3   Mission Critical Failures

Mission Operations design shall prevent the introduction of mission critical failures caused by operational error or ground equipment failure.

A mission critical failure is one that results in the permanent loss of data from more than one science instrument, the permanent loss of science-critical attitude determination data, the failure to achieve and maintain the proper mapping orbit or spacecraft pointing control, or the failure to achieve the quarantine orbit.

The following techniques shall be used unless the failure is found to be acceptably improbable.

3.3.3.1   Operational Errors

All mission activities involving operator input (e.g. command loads) shall have the input constraint checked and verified, with the exception of science non-interactive commands.

3.3.3.2   Ground Equipment Failure

Operations activities shall be designed to preclude a malfunction of a ground element at a specific time from causing a mission failure.

If an activity is identified which does require a ground element functioning properly at a specific time then the ground system shall employ redundant elements unless it can be shown that the failure/repair time is within an acceptable window for the identified activity.

3.3.3.3   Project Supplemental Support

Project personnel shall supplement the monitoring performed by institutional personnel during launch, trajectory correction maneuvers, Mars orbit insertion, aerobraking maneuvers, if required, and spacecraft emergency periods.

3.3.4   Degraded Operation

The MOS design shall accommodate operation in a degraded mode, defined to be a mode in which the primary scientific objectives of the mission can still be met, but at the expense of reduced performance, increase in operations costs, or loss of scientific data.

3.3.5   Data Base / Data Records

3.3.5.1   Project Data Base (PDB)

A project data base (PDB) shall be established for the purpose of staging and disseminating all project information for project use.

The data base shall:

(a)   contain at least 3 weeks of mission data on-line;

(b)   have an on-line capacity of at least 14 Gbytes;

(c)   provide recall of up to 1 Gbyte of data within 1 working day;

(d)   provide for a total mission repository of at least 900 Gbytes; and

(e)   remain in existence until end of project (April 1, 2003).

3.3.5.2   Archival Data Transfer

Mission operations shall provide for transfer of a level zero archival record to the Planetary Data System. Final transfer shall occur on or before end of project (April 1, 2003).

3.3.6   Telescience

3.3.6.1   Distributed Data System

Mission operations shall be performed using a distributed data system. That data system shall provide the principal investigator, team leader and interdisciplinary scientist the capability to perform their flight operations functions from their home institution.

3.3.6.2   Support Priority

The distributed data system shall support, in order of priority:

(a)   Instrument health assessment

(b)   Sequence planning and execution

(c)   Science data transfer

(d)   Science data analysis and transfer

3.3.6.3   Data Delivery Time

The mean time for availability of telemetry data to each principal investigator or team leader shall not exceed 24 hours from time of ground receipt.

3.3.7   Data Return Percentage

Mission Operations sequence planning and implementation shall return at least 86% of the science data available during the mapping phase.

3.3.8   Flight Sequence Process

Mission Operations sequence activities shall be designed to be performed over a maximum period of 56 days (i.e., from start of sequence development through completion of the sequence execution on-board the spacecraft). Sequences shall be established as a number of simple command segments; each segment shall possess a high degree of repeatability. The segments shall be constructed using relative time offsets. The absolute start time of a sequence or segment shall be changeable by ground command. Pre-launch, a Mission Sequence Plan shall identify these sequences and their utilization during the mission. The process shall capitalize on the architectural separation of the spacecraft and payload functions.

3.3.8.1   Sequence Development

All flight sequences, for the spacecraft bus and payload, shall be developed using the MOS. Sequence durations shall be as long as possible, consistent with ground timing accuracies and spacecraft sequence memory constraints.

3.3.8.2 Sequence Implementation Cycle

A flight sequence implementation cycle shall be followed in which flight sequences will be developed, validated, approved and uplinked to the spacecraft. The pre-launch developed critical sequences will be updated, validated, approved and uplinked in this process.

3.3.8.3 Sequence Verification and Validation

The MOS shall ensure that all sequences developed and transmitted to the spacecraft do not violate the rules defined in the Flight and Mission Rules document and meet the mission objectives as implemented in the Mission Sequence Plan.

The MOS shall define sequence validation criteria and all flight sequences meeting the criteria shall be tested with the Spacecraft Test Laboratory (STL), before uplink to the spacecraft.

Project identified mission critical sequences shall be tested with the spacecraft and the STL prior to launch.

Note that science non-interactive commands, defined as those commands which are routed directly to the PDS and do not affect spacecraft resources (e.g., power, propellant, CDS stored sequence memory, etc.), are not constrained by this requirement.

3.3.9 Real-Time Command Process

Mission Operations shall be capable of preparing the real-time commands required to load flight sequences (as defined in Paragraph 3.3.8) and other non-stored command types, including spacecraft and payload interactive commands, emergency commands, flight software load changes, and science non-interactive commands.

3.3.9.1 Command Verification and Validation

Mission Operations shall ensure that all real-time interactive commands developed and transmitted to the spacecraft do not violate the rules defined in the Flight and Mission Rules document, nor jeopardize meeting mission objectives.

Mission Operations shall define real-time command validation criteria and all real-time commands meeting the criteria shall be tested with the Spacecraft Test Laboratory (STL), before uplink to the spacecraft.

3.3.9.2 Science Non-Interactive

Mission Operations shall be capable of expediting the generation and transmission of science non-interactive command requests, by bypassing the normal validation and approval process for interactive commands.

3.3.10   Flight Sequence Adaptability

3.3.10.1   Flight Sequence Change Control Process

During the flight sequence implementation cycle, changes to the flight sequences shall be controlled via a flight sequence change control process.

3.3.10.2   Changes to Onboard Sequences

After uplink, flight sequences shall only be changed to update navigation position and timing information, which if not made would prohibit or jeopardize meeting mission objectives.

3.3.11   Flight Software Reprogramming

Reprogramming of the spacecraft or payload data subsystem flight software during the mission shall be performed, only if the risk of not doing so would prohibit or jeopardize meeting mission objectives.

3.3.12   Project Staffing Period

Project operations shall be based on an 8 hour shift and a five day work week for normal cruise and mapping operations. Allowances shall be made for critical activities such as launch, MOI, and aerobraking.

3.3.13   Maneuvers

MOS shall be capable of supporting maneuvers as frequently as every 10 days during the orbit insertion phase and every 14 days during the mapping phase. MOS shall be capable of supporting aerobraking maneuvers once every day, during the orbit insertion phase.

3.3.14   Ephemerides

3.3.14.1   Planetary Ephemeris

MOS shall produce and uplink an on-board planetary ephemeris on a schedule required to maintain telecommunications link margin requirements.

3.3.14.2   Spacecraft Ephemeris for Nadir Pointing

If the spacecraft nadir pointing control function should require an on-board ephemeris, this ephemeris shall be produced and uplinked on a schedule that supports 10 mrad (per axis, 3σ) pointing accuracy.

SECTION 4 TRACKING AND DATA ACQUISITION (TDA) SYSTEM REQUIREMENTS

This section documents the requirements on the Tracking and Data Acquisition System from each of the three elements of the mission system (mission design, navigation design, and mission operations design).

4.1 TDA REQUIREMENTS FROM MISSION DESIGN

4.1.1 DSN Coverage

The DSN shall provide tracking coverage for spacecraft data return, monitoring, commanding, and radiometric tracking data as defined in Table 3-2.

4.1.2 DSN Lockup Time

The DSN shall provide carrier signal lockup, telemetry data lockup, and telemetry frame synchronization within 5 minutes following arrival of the spacecraft downlink signal at the tracking station for data rates of 18.6 kbps or greater. During the mapping phase, pass reacquisition (after earth occultations) shall occur within one minute of arrival of signal.

4.2   TDA REQUIREMENTS FROM NAVIGATION DESIGN

4.2.1   Tracking Data Acquisition Requirements

The acquisition and data conditioning process shall be designed such that the data accuracy requirements are maintained and there is a high probability (99% for Doppler data and 95% for ranging data) that all data are valid.

4.2.2   Tracking Data Accuracy and Calibrations

The contribution of the DSN to the tracking data error, due to station hardware or instrumental effects and radio signal propagation through the Earth's atmosphere and interplanetary medium, are specified in Table 4-1.

The following tracking data calibrations are required.

a)   Doppler corrections or calibrations are required for the Earth's atmospheric effect (troposphere and ionosphere).

b)   Timing and polar motion polynomials or information, compatible with the Orbit Determination Program (ODP) software, are required.

c)   The range data shall be calibrated for atmospheric effects, ground instrument effects and spacecraft time–delay.

Table 4–1   Tracking Data Accuracy Requirements

Tracking Data	DSN Accuracy (3σ)	End to End System* Accuracy (3σ)
Two–way coherent Doppler (60 sec), mm/sec	0.54	0.60
Round–trip travel time or range, meters	13.4	15.0
Differenced Doppler (60 sec), mm/sec	0.16	0.18

*   The end to end system tracking data accuracy requirements include contributions from the spacecraft and the DSN.

4.2.3   DSN Tracking Station Coordinates and Accuracy

         The cylindrical coordinates of all tracking stations used to acquire navigation data are required. Absolute and relative accuracies are specified in Table 4–2.

Table 4–2.   Tracking Station Coordinate Accuracy Requirement

a)   Absolute Accuracy –

Coordinate	Accuracy (3σ, meter)
Longitude, l (equivalent distance)	0.69
Distance from spin axis, r_S	0.54
Distance perpendicular to Earth's equatorial plane, z	0.70

b)   Relative Accuracy –

Relative station coordinates shall be accurate to 30 cm (3σ). A complete set of station coordinates and an error covariance matrix shall be provided to navigation consistent with the planetary ephemeris used for flight operations.

4.2.4   Data Conditioning and Data Delivery

         The DSN shall provide all available radiometric data obtained during scheduled DSN passes. Raw navigation data shall be provided in the form of an Archival Tracking Data File (ATDF). The raw navigation data shall also be conditioned (i.e. data sampling, elimination of erroneous data, and application of calibrations) and provided in the form of an Orbit Data File (ODF). The ATDF and ODF shall be provided in Standard Formatted Data Unit (SFDU) format to the AMMOS.

4.2.4.1   Radiometric Data Delivery Schedule

         a)   Nominally edited ODF files shall be provided to the Navigation Team twice per week during the interplanetary phase. Exceptions are as follows:

              1)   During periods of intense navigation activity, such as injection, TCMs, and the MOI maneuver, ODF files are generally required within one hour of the end of the tracking pass. Partial data files may be required during a tracking pass.

              2)   Special conditions apply during the launch phase. During the first several tracking passes, radiometric data deliveries are required every hour.

b)	During the orbital phase, edited ODF files are required 12 hours after the end of a tracking pass (excluding weekends). If this time should occur outside of normal working hours 8:00 a.m. to 5:00 p.m. local time (Monday through Friday) then that data shall be available to the Navigation Team by 8:00 a.m. of the next working day. Exceptions are as follows:

1)	For all propulsive maneuvers during the orbit insertion phase data will generally be required within one hour of the end of the tracking pass.

2)	During mapping tracking data are required within 1 hour of the end of a pass whenever a propulsive maneuver occurs within that pass. This is subject to the normal working hour guidelines given in (b) above.

3)	Data files shall be provided twice per day, including weekends, during selected portions of the aerobraking phase.

4.3   REQUIREMENTS ON TDA FROM MISSION OPERATIONS DESIGN

4.3.1   General

The Mars Global Surveyor Project plans to make use of the DSN capabilities as described in 810-5 Revision D (Ref. 5) for mission support. It is assumed that the performance capabilities and accuracies described therein will be available to support the Mars Global Surveyor Mission. Additional capabilities, such as X-band uplink, initial acquisition of X-band, and Standard Formatted Data Unit (SFDU) data transmission to the Multi Mission Ground Data System (MGDS) are called out specifically in this document.

4.3.2   Facility Use

Project requirements for DSN coverage are specified in Table 3-2. All DSN facilities (Deep Space Communications Complex, Ground Communications Facility, Network Operations Control Center) associated with this support are included.

Prelaunch the Project shall require the services of DTF-93 (formerly CTA-21) and the Compatibility Test Trailer (CTT) for interfacing with the spacecraft at the contractor spacecraft development facility, DSN compatibility testing and MOS test and training. During pre-launch operations at ELS the Project shall require the services of MIL-71 (or a similar facility with the same capabilities) for interfacing with the spacecraft in support of final DSN spacecraft compatibility tests and MOS end-to-end tests. The specific dates and support requirements will be provided.

The DSN shall schedule its facilities to meet Project requirements.

4.3.3   Telemetry

The DSN shall support X-band downlink telemetry as defined in Table 3-2 at rates of 10, 256, 2000, 8000, 16000 and 32000 bps, and at Reed- Solomon encoded rates of 4, 8, 16, 21.3, 32, 40, 42.7, 64, 80 and 85.3 ksps.

Telemetry data shall be provided to the AMMOS in the form of convolutionally decoded, "transfer frame" synchronized, real-time data streams in SFDU format. The DSN shall ensure that all committed telemetry data are provided to the AMMOS within 12 hours of receipt by the Deep Space Communications Complex (DSCC) and that all successfully received data is not permanently lost due to ground communications failure. The DSN shall maintain a backup of mission critical data for 30 days. The DSN shall have the capability of Reed-Solomon decoding the data at the DSCC.

4.3.4   Command

The DSN shall provide X-band command capability on all scheduled passes as defined in Table 3-3 at 7.8125, 31.25, 62.5, 125, 250 and 500 bps. The nominal rate shall be 125 bps ; the higher rates may be used if command link performance permits. Emergency commanding capability at 7.8125 bps at maximum Mars range with adverse spacecraft low gain antenna orientation is required from at least one DSN station.

4.3.5   Simulation

        The DSN shall generate simulated telemetry data streams for all spacecraft data rates. In addition, the DSN shall support a "long-loop" simulation data interface with the MGSO. These capabilities are required at all DSN facilities supporting the Project, including DTF-93 and MIL 71.

4.3.6   Communications

        The DSN shall provide data and voice communications between the MGSO and DSN facilities committed to support mission operations as part of the DSN support requirements defined in Table 3-2.

        Pre-launch the DSN shall provide communications during spacecraft System Test for data and voice transmission between the Spacecraft Contractor facility and JPL.

        Pre-launch and launch the DSN shall provide launch data and voice communications support between ELS and JPL.

        The Project requires data communication links between the JPL AMMOS and each of the Mars Global Surveyor Principal Investigators, Team Leaders and Interdisciplinary Scientists. These communications lines with modems are to be provided by NASCOM. A link is required between JPL and each of the following locations.

        a. GSFC
        b. Stanford University
        c. Arizona State University
        d. Ames Research Center
        e. University of Colorado
        f. U.S. Geological Survey at Menlo Park
        g. Washington University at St. Louis
        h. California Institute of Technology
        i. Malin Space Science Systems at San Diego

4.3.7   Error Rate

        The rate of undetected errors produced by the DSN in data received or generated by the DSN shall not exceed 10^{-7}. Data containing known uncorrected errors shall be recorded for analysis. The rate of packet loss produced by the DSN shall not exceed 0.5×10^{-4}.

4.3.8   Test and Training

        All DSN facilities committed to support launch and cruise flight operations shall participate in Project MOS test and training functions to be conducted prior to launch. All DSN facilities committed to support encounter flight operations shall participate in Project MOS test and training functions to be conducted post launch.

4.3.9   Monitoring Services

        The DSN shall perform services during the tracking pass that give indication of spacecraft, telecommunication and DSN system performance. These services shall include alerting the Project of abnormal or anomalous conditions.

4.3.10   Project Interface

        The DSN shall establish an operational point of contact for the Project. All committed DSN negotiated products are to be delivered to the Project via AMMOS or other negotiated interfaces.

4.3.11   DSN Monitor Data

        The DSN shall provide monitor data in SFDU format in real-time to the MGSO as defined in Table 3-2 including pre-launch activities.

4.3.12   Spacecraft Acquisition

        Following launch, the DSN Canberra complex shall acquire the spacecraft X-band signal. This initial acquisition shall occur within 30 minutes of the spacecraft turning on its RF transmitter. The DSN shall be capable of performing this function out to an earth-to-spacecraft range of 40,000 km .

        During cruise, orbit insertion and mapping phases, pass acquisitions shall occur within 5 minutes of predicted telemetry signal reception. During the mapping phase, pass reacquisitions (after Earth occultations) of the spacecraft downlink telemetry shall occur within 60 seconds of telemetry signal reception.

4.3.13   Data Return

        The DSN shall capture and transfer to MGSO at least 95% of the available science data received at the DSN antenna during the mapping phase.

SECTION 5 LAUNCH SYSTEM REQUIREMENTS

This section documents the requirements on the Launch System from each of the three elements of the mission system (mission design, navigation design, and mission operations design).

5.1   LAUNCH SYSTEM REQUIREMENTS FROM MISSION DESIGN

5.1.1   Injection Energy

The launch vehicle performance shall provide an injection energy per unit mass of 10.41 km^2/s^2, at a launch asymptote declination less than or equal to 28.7 deg for an injected mass of 1060 kg. The launch vehicle shall also be capable of providing an injection energy per unit mass of 9.24 km^2/s^2, at a launch asymptote declination less than or equal to 36.5 deg for an injected mass of 1060 kg.

5.1.2   Probability of Command Shutdown

The minimum acceptable Delta second stage probability of command shutdown (PCS) shall be 95.0%

5.1.3   Launch Period Duration

The launch system shall support a 21 consecutive day launch period in November 1996, which allows the spacecraft system to achieve an Earth-Mars trajectory.

5.1.4   Daily Launch Windows

Within the constraints of launch operations, the launch system shall support two instantaneous daily launch windows for the first half of the launch period.

5.1.5   Spacecraft Attitude Constraint

The spacecraft +Z-axis shall be maintained at an angle greater than 30.0 deg relative to the sun-spacecraft line. For those periods of time when the spacecraft +Z-axis must be less than 30.0 deg from the sun-spacecraft line, a slew rate of greater than 0.4 deg/s shall be maintained.

5.1.6   Collision and Contamination Avoidance

The upper stage shall neither collide with or contaminate the spacecraft after separation.

5.2   LAUNCH SYSTEM REQUIREMENTS FROM NAVIGATION DESIGN

5.2.1   Injection Accuracy

The injection accuracy Figure of Merit (FOM) shall not exceed 24 m/s at 15 days after launch for all trajectories to be used for the mission.

5.2.2   Injection–Error Covariance

A set of 6x6 injection–error covariance matrices shall be provided throughout the launch period. The delivery schedule is as follows:

11/01/95	for final target specification/flight operations
Launch –6 months	for flight operations

5.2.3   Injection State

Launch/injection state vectors corresponding to each launch date and time are required no later than 6 months prior to the initial launch date.   Representative state vectors shall be provided 12 months prior to the initial launch date. The form and content shall be specified by the Navigation Team.

5.3   LAUNCH SYSTEM REQUIREMENTS FROM MISSION OPERATIONS DESIGN

The MOS has no requirements on the launch system.

SECTION 6 SPACECRAFT SYSTEM REQUIREMENTS

This section documents the requirements on the Spacecraft System from each of the three elements of the mission system (mission design, navigation design, and mission operations design).

6.1   SPACECRAFT SYSTEM REQUIREMENTS FROM MISSION DESIGN

6.1.1   Lifetime

The spacecraft shall have an on-orbit design life such that it can operate successfully for at least five Earth years on-orbit for the mapping and relay phases and maneuver to a quarantine orbit, if required, at the end of the relay phase.

6.1.2   Launch Period

The spacecraft shall be capable of supporting a 21 consecutive day launch period, with launch on any day in the launch period. The spacecraft shall be capable of supporting the two instantaneous daily launch windows on each launch day.

6.1.3   Launch Mass

At launch, the spacecraft mass, including GFP, propellants, pressurant and adapter shall not exceed 1060 kg. The propellant mass shall be capable of providing the delta-V specified in 6.1.4 with a 99% confidence.

6.1.4   Total Delta-V

The spacecraft shall provide a total mission delta-V capability of 1290 m/s. This number includes and assumes 35 m/s for finite burn losses from thrust vector misalignment losses, gravity losses, and all other maneuver inefficiencies, and 92 m/s for rotational attitude control.

A 99% low engine specific impulse shall be used for computing the propellant load required.

6.1.5   Cruise Phase Maneuvers

The spacecraft shall be capable of executing at least four trajectory correction maneuvers (TCMs), in any inertial direction and at any time during the cruise phase.

6.1.6   Orbit Insertion Maneuvers

The spacecraft shall be capable of executing a series of propulsive maneuvers and aerobraking methods to achieve delivery from a northern approach trajectory to Mars into the mapping orbit.

The spacecraft shall be capable of establishing a capture orbit, propulsively, with a period less than or equal to 48 hours and a periapsis radius greater than or equal to 3700 km.

The spacecraft shall utilize aerobraking and propulsive manevuers to lower the orbit from the initial capture orbit to the mapping orbit. Aerobraking shall be terminated when sufficient propulsive capability is available to transition to the mapping orbit. The spacecraft shall be able to accommodate the aerodynamic heating rates and dynamic pressures encountered during the passes through the atmosphere to achieve a 2:00 p.m. local mean solar time descending node crossing.

6.1.7   Planetary Protection

If any part of the spacecraft is jettisoned after injection into the trans-Mars trajectory, it shall be shown by analysis that the probability of accidental impact of the jettisoned part on Mars shall be less than 10^{-2} up to 20 years after launch and 0.05 for an additional 30 years.

6.1.8   Mapping Orbit Domain

The spacecraft shall be capable of establishing and operating within specification in a mapping orbit within the range of orbital elements shown in Table 6-1.

Table 6-1   Mapping Orbit Mean Elements (averaged over one orbit)

Orbit Element[1]	Minimum Semi-Major Axis	Maximum Semi-Major Axis
Semi-major Axis, km	3775.1	3797.2
Eccentricity	0.0072 ± 0.007	0.0072 ± 0.007
Inclination, deg	92.87	92.93
Ascending Node, deg[2]	$-39.1664 + 0.524T \pm 3$	$-39.1664 + 0.524T \pm 3$
Argument of Periapsis, deg	-90 ± 10	-90 ± 10
Mean Anomaly, deg	Arbitrary	Arbitrary

[1]   The coordinate system is the Mars equator and IAU vector of epoch.
[2]   T is Earth days past January 1, 1998 at 0000 hours ET.
      The ascending node is located on the night side of the planet.

6.1.9   Orbit Trim Maneuvers

The spacecraft shall be capable of executing OTMs during the mapping and relay phases as frequently as every 7 days. The spacecraft shall be capable of executing the velocity increment for an OTM in any inertial direction.

6.1.10   Mapping Orbit Attitude Reference

During the mapping and relay phases, the spacecraft shall be capable of maintaining the nadir-pointing attitude defined by the orbital reference coordinate system, contained in Appendix A.

6.1.11   Solar Conjunction

The spacecraft shall be capable of functioning without ground commands and of performing the minimum functions required for safe operation during the periods when the Sun-Earth-Mars angle is less than 2 degrees (from May 4 to May 21, 1998, from June 25 to July 8, 2000, and from August 2 to August 17, 2002). When exiting the solar conjunction period, the spacecraft shall be capable of receiving a transmitter ON ground command and supporting a normal acquisition by the DSN.

6.1.12   Uplink

The spacecraft shall have the capability to receive an X-band carrier, phase-modulated with command and range subcarriers. The spacecraft shall be capable of providing a primary uplink path sufficient for simultaneous high-rate commanding and two-way coherent Doppler tracking via a 34-m (HEF) Deep Space Station (DSS) at maximum range.

6.1.13   Command Rates

The spacecraft shall be capable of accepting at least two, in-flight switchable, uplink command rates. The higher rate, 125 bps, shall be used for normal day-to-day commanding. The lower rate, 7.8125 bps, shall be used as a backup or emergency mode.

6.1.14   Emergency Uplink

The spacecraft shall be commandable via a 34-m (HEF) DSS at the emergency uplink rate of 7.8125 bps when the Earth-spacecraft range $\leq$ 2.67 AU.

6.1.15   Downlink

The spacecraft shall be capable of transmitting a X-band carrier to telemeter science, engineering, and navigation data.

6.1.16   Cruise and Orbit Insertion Downlink

The spacecraft design shall satisfy the following requirement during one 34m-HEF DSN pass per day. During cruise and orbit insertion phases, the spacecraft shall provide an effective isotropic radiated power (EIRP) that is sufficient to return the minimum data required to characterize the health and performance of the spacecraft, to return the results of the science calibrations, and to provide the required navigation data types at the required accuracies.

6.1.17   Mapping and Relay Phase Downlink

During the mapping and relay phases, the spacecraft shall be capable of providing an EIRP sufficient to meet the navigation tracking requirements in Table 3-2 and to support minimum combined science and engineering data rates described in the Payload Data Subsystem Functional Requirements Document (Ref. 4) when the spacecraft is at maximum range (2.67 A.U.).

6.1.18   Mapping Phase Science Data Return

During the mapping phase, the spacecraft shall be capable of continuously (with the exception of data storage management activities and orbit trim maneuvers) gathering and storing science and engineering data. The spacecraft shall be capable of transmitting these data to Earth as follows:

6.1.18.1   Recorded Science Data Return

Every day, the spacecraft shall be capable of transmitting to Earth 24 hours of recorded combined science and engineering data during an approximate 4.5-hour (non-continuous due to Earth occultations) ground station contact period (i.e., a single DSN pass).

6.1.18.2   Real-Time Science Data Return

Every third day, {and daily for two periods of 4 weeks duration each}, the spacecraft shall be capable of transmitting to Earth real-time high-rate combined science and engineering data during a second 4.5-hour (non-continuous) ground station contact period.

6.1.18.3   Science Campaign Data Return

Data return during science campaigns during mapping which require continuous spacecraft downlink are limited to the power available.

6.1.19   Data Rates

The spacecraft shall accommodate the science instrument data rate inputs as defined in the PDS- Instruments Interface Requirements Document (Ref. 3) and the PDS data rate outputs as defined in the Payload Data Subsystem Functional Requirements Document (Ref. 4).

6.1.20   Data Streams

The spacecraft shall provide for the following data streams:

(a)   A combined science and engineering data stream that can be recorded for later playback or returned in real time.

(b)   A high-rate combined science and engineering data stream for real time transmission only.

(c)   An engineering only stream that can be transmitted in real time or recorded for later playback.

6.1.21   Data System Modes

The spacecraft shall provide the following data acquisition and transmission modes:

(a)   Record the combined science and engineering data stream

(b)   Record the combined science and engineering data stream while simultaneously playing back recorded combined science and engineering data

(c)   Record the combined science and engineering data stream while simultaneously downlinking in real time any one of the three data streams (combined science and engineering, high rate real time combined science and engineering, and engineering only)

(d)   Playback recorded science and engineering data stream

(e)   Downlink in real time any one of the three data streams (combined science and engineering, high rate real time combined science and engineering, and engineering only)

(f)   Record the engineering only data stream

(g)   Playback recorded engineering only data

6.1.22   Data Storage Capability

The data storage capability shall be sufficient to continuously record the combined science and engineering data stream, up to the maximum 16-ksps symbol rate (13952 bps), for a minimum of 24 hours.

6.2   SPACECRAFT SYSTEM REQUIREMENTS FROM NAVIGATION DESIGN

6.2.1   Tracking Data

The spacecraft shall be capable of supporting the tracking schedule for returning navigation data as defined in Table 3-2, excluding periods of earth occultation. The spacecraft shall support Table 3-2 requirements on a best efforts basis during solar conjunction.

6.2.2   Antenna Phase Center Motion

Mechanically induced antenna phase center motion shall not be greater than 0.1 mm/sec (1) with a 60 second integration time with respect to the spacecraft's center of mass except during momentum management periods.

6.2.3   Angular Momentum Desaturation

The spacecraft shall provide engineering telemetry to determine the start time of momentum management events and to support reconstruction of disturbance forces induced by momentum management.

6.2.4   Propulsive Maneuver Execution Errors

Maneuver execution errors have two components: (1) magnitude errors that are measured parallel to the desired impulse direction and (2) side–velocity errors that are measured perpendicular to that direction. The error model assumes that the error in each component is made up of a fixed error, which is independent of the impulse magnitude, and a proportional error, which is proportional to the impulse magnitude. For each component of each maneuver, the allowable error shall be less than the RSS of the 3 fixed and proportional error limits shown in Table 6–2.

Table 6–2. Maneuver Execution Error Limits (3)

Error Source	Error Limit
Proportional Magnitude	2.0%
Fixed Magnitude	0.05 m/s
Proportional Side Velocity (Total)	2.5%
Fixed Side Velocity (Total)	0.01 m/s

Note: The proportional side velocity error corresponds to a pointing error of 25 mrad.

6.3   REQUIREMENTS ON SPACECRAFT SYSTEM FROM MISSION OPERATIONS
DESIGN

6.3.1   Launch

6.3.1.1   Uplink

         The spacecraft shall execute its launch sequence without requiring ground commands
by the MOS. The spacecraft shall not require a ground command prior to spacecraft/ upper stage
separation plus 48 hours.

6.3.1.2   Downlink

         The spacecraft shall provide an RF downlink at least 30 minutes prior to the
spacecraft reaching a 30,000 km range from Canberra, if transmitting at 2000 bps, or 40,000 km
range if transmitting at 10 bps.

6.3.2   Autonomous Operation

6.3.2.1   Autonomous Safing

         In the event of a failure, the spacecraft shall autonomously maintain, for at least 72
hours, the minimum functions required for safe system operation, including payload protection
from abnormal spacecraft states or attitudes.

6.3.2.2   Emergency Commands

         Spacecraft fault tolerance mechanisms shall configure the spacecraft suitable for
receipt of fault recovery commands following fault detection, without ground action. The
spacecraft bus shall provide, at a minimum, a reduced performance uplink with a minimum G/T
(mean -3) of -28.2 dB/K referenced to the antenna output terminals.

6.3.2.3   Emergency Telemetry

         In the event of a failure that disrupts normal ground-spacecraft communication
schedules, the spacecraft bus shall return emergency engineering data. The spacecraft shall also
initiate emergency telemetry in the event that no commands are received within a ground selectable
time. The data volume within a single DSN pass shall be sufficient to determine the spacecraft
state.

6.3.3   Command Requirements

         The spacecraft shall be capable of performing its required functions through the use
of on-board stored operating programs, stored sequence commands and ground transmitted real-
time commands.

6.3.3.1   Operating Programs

Functions controlled by on-board operating programs that are dependent on spacecraft performance or mission operations activities shall be changeable through ground issued commands in the form of memory loads.

6.3.3.2   Stored Sequence Commands

The spacecraft shall provide on-board storage and subsequent issuance of stored sequence commands for control of bus and payload operations. At least 1500 16-bit payload time-tagged sequence commands are required.

6.3.3.3   Real Time Commands

The spacecraft shall take immediate action in response to receipt of real-time commands. Real-time commands include the transfer of payload memory load words.

6.3.3.4   Error Protection

The spacecraft design shall require all commands (including commands comprised of multiple words) to be validated upon receipt by the spacecraft, before being allowed to execute. The spacecraft design shall also require that critical or non-reversible commands be confirmed prior to their issuance.

6.3.3.5   Uplink Frequency

The spacecraft design shall minimize the frequency and volume of ground commands required to maintain safe operation, and the complexities associated with configuring the spacecraft for necessary commanding.

6.3.3.6   Time-Critical Commands

The spacecraft shall not require time-critical transmission of ground commands. Time critical commands are defined to be real-time commands, which if not received by the spacecraft within 72 hours, may jeopardize or prohibit meeting the mission objectives.

6.3.3.7   Command Rate Visibility

The spacecraft design shall make it possible to unambiguously determine the spacecraft command rate at all times.

6.3.4   Engineering Data Requirements

6.3.4.1   Health Assessment

The spacecraft shall provide data sufficient to perform an assessment of the current health of the spacecraft bus through the telemetry downlink during each DSN ground station contact period consistent with spacecraft operating modes and critical mission events.

6.3.4.2   Consumable Status

The spacecraft engineering telemetry shall provide measurements to allow determination of the quantity of consumables remaining on the spacecraft.

6.3.4.3   Memory Contents and Validation

The spacecraft shall be capable, via ground command, of reading out any or all its memory through telemetry. The spacecraft shall also provide for a technique of validating its memory without having to perform a complete memory readout.

6.3.4.4   Performance Visibility

The spacecraft shall provide indicators in the telemetry stream regarding its condition. The indicators shall be predictable to allow assignment of limits to be checked by ground-based equipment for purposes of monitoring spacecraft health. These indicators shall also be used to support long-term trend analysis.

6.3.4.5   Command Verification

The spacecraft shall provide information in the telemetry stream to allow determination of command receipt and execution.

6.3.4.6   Pointing Reconstruction

The spacecraft telemetry shall include sufficient attitude reconstruction data which, when combined with the orbit reconstruction data with accuracies shown below, allow reconstruction of the nadir panel pointing to within ±3 mrad (per axis, 3σ).

Position Component	3σ Uncertainty in the Reconstructed Position of the Spacecraft, km
Downtrack	9
Crosstrack	5
Radial	2

6.3.5   Spacecraft Ephemeris Prediction

During the mapping phase, if any spacecraft function depends on the ability of the MOS to predict the ephemeris of the spacecraft, the analysis of that function shall be based on the worst case ground ephemeris prediction capability given below.

3   Uncertainty in the Predicted Position of the Spacecraft, km

Position Component	Perihelion 1 (1/7/98)	Perihelion 2 (11/25/99)
Downtrack (DT)	20*	150*
Crosstrack (CT)	9	9
Radial (R)	8	8

*   DT errors are driven by the atmospheric density uncertainty; a 95% confidence level was used.

6.3.6   Data Recorder Management

The spacecraft shall be capable of providing for on-board management of the data recorder playback to prevent data loss resulting from Earth occultations and associated DSN lockup time requirements, not to exceed 5 minutes per orbit.

6.3.7   Spacecraft Clock

The spacecraft clock shall be capable of being correlated with a known epoch to within 20 msec. The stability of the clock frequency source shall be such that the total drift over a 21 day period is predictable to an accuracy of 20 msec.   The spacecraft shall provide an unambiguous count with each data frame in accordance with JPL-D-1672 (Ref. 2) from launch through the end of the mission.

6.3.8   Data Return Percentage

The spacecraft shall transmit to the DSN at least 86% of the available science data, as commanded via the stored sequence during the mapping phase.

6.3.9   Data Standards

The spacecraft shall conform to the data standards presented in the Consultative Committee for Space Data Standards (CCSDS) documents (Ref. 1).

6.3.10   Sequence Test

Project identified mission critical sequences shall be tested with the spacecraft and the STL prior to launch.

6.3.11   Autonomous Eclipse Detection and Command Initiation

        While in orbit about Mars, the spacecraft shall have the capability to autonomously detect eclipse entry and exit with an accuracy of less than or equal to 15 seconds. Upon eclipse entry and exit detection, respectively, the spacecraft shall be capable of initiating a ground specified stored command sequence. It shall be possible to enable/disable this capability by real-time or stored sequence command.

6.3.12   Autonomous Equator Crossing Detection and Command Initiation

        While in orbit about Mars, the spacecraft shall have the capability to provide a time reference to the PDS containing both the upcoming and subsequent ascending node equator crossing times approximately 7 minutes before the first of these two events.

SECTION 7 SCIENCE SYSTEM REQUIREMENTS

This section documents the requirements on the science system from each of the three elements of the mission system (mission design, navigation design, and mission operations design).

7.1   SCIENCE SYSTEM REQUIREMENTS FROM MISSION DESIGN

7.1.1   Altitude Variation

Instruments shall be able to accommodate areographic altitudes between 351 to 455 km.

7.1.2   Cruise and Orbit Insertion Phase Science

Science activity during the cruise and orbit insertion phases shall be planned pre-launch and be consistent with the inherent capabilities of the spacecraft and with a policy of minimizing complexity, risk, and resource utilization in mission operations. First priority shall be given to essential instrument calibrations which cannot be performed during the mapping phase.

7.2 SCIENCE SYSTEM REQUIREMENTS FROM NAVIGATION DESIGN

No Requirements

7.3   SCIENCE SYSTEM REQUIREMENTS FROM MISSION OPERATIONS DESIGN

7.3.1   Data Standards

          The payload shall conform to the data standards presented in the Consultative Committee for Space Data Standards (CCSDS) documents (Ref. 1).

7.3.2   Payload Sequence Capability

          The payload shall be capable of conducting its observations by following the flight sequence implementation cycle described by 3.3.8, or by the non-interactive command request described by 3.3.9.2

7.3.3   Instrument Health Monitor

          During the mapping phase each Principal Investigator shall be responsible for assessment of the health of his/her instrument and shall inform the Project of its condition on a daily or standard workshift basis.

7.3.4   Science Analysis

          Each Principal Investigator, Team Leader and Interdisciplinary Scientist shall be responsible for the analysis of the data pertaining to his investigation. Furthermore, the Principal Investigators, Team Leaders, and Interdisciplinary Scientists shall be responsible for the acquisition and maintenance of computers, software or personnel required for performance of that analysis.

          The PI's, TL's, and IDS's shall provide an acknowledgment of acceptance of MOS products.

7.3.5   Science Data Archival

          Each Principal Investigator shall be responsible for submitting his/her processed science data and data products to the Planetary Data System.

SECTION 8   MULTIMISSION GROUND SYSTEM OFFICE (MGSO) SYSTEM
                 REQUIREMENTS

         This section documents the requirements on the MGSO system from each of the three
elements of the mission system (mission design, navigation design, and mission operations
design).

8.1   MGSO SYSTEM REQUIREMENTS FROM MISSION DESIGN - No Requirements

8.2   MGSO SYSTEM REQUIREMENTS FROM NAVIGATION DESIGN

8.2.1   Planetary Ephemeris

MGSO shall provide a J2000 referenced Planetary ephemeris (on the navigation computer and project database) one year prior to launch. The ephemeris accuracy shall be equal to, or better than, the DE 234 planetary ephemeris accuracy. At Mars encounter, the RSS position uncertainty is 21 km (3) .

8.2.2   Mars Natural Satellite (Phobos & Deimos) Ephemeris

MGSO shall provide a J2000 referenced natural satellite ephemeris on the navigation computer one year prior to launch. The ephemeris shall extend for the duration of the mission.

8.2.3   Computation Support Requirements

a)   MGSO shall provide a multimission navigation computer system which will be available to support MGS development and certification during FY '94 and FY '95. Starting FY '96 this system shall be operational to support MGS GDS test and preparations for flight operations.

MGSO shall provide a second navigation computer system which shall be for MGS use as a redundant multimission navigation computer to be operational by launch minus twelve months.

b)   If these computers reside on the operations LAN, MGSO shall provide System Administration support.

8.2.4   Radiometric Data Storage

The MGSO shall accept radiometric data from the DSN and store these data on the project data base.

8.3   MGSO REQUIREMENTS FROM MISSION OPERATIONS DESIGN

8.3.1   General

The Mars Global Surveyor Project plans to use the MGSO AMMOS capabilities as described in MGSO 20-01 (Ref. 6) for mission support. It is assumed that the capabilities described therein will be available to support the Mars Global Surveyor Mission. Additional capabilities, such as Project Data Base, science workstations and interface to the Planetary Data System are called out specifically in this document.

8.3.2   Facility Use

The MGSO shall support the Mars Global Surveyor Project for all coverage periods specified in Table 8-1. All MGSO services and Project access capabilities to the Project data, the Project Operations Support Area (POSA) and the remote science workstations are included.

Pre-launch the MGSO shall provide a development environment (hardware, software and facility space) to support Project software development.

During the periods the spacecraft is at the spacecraft contractor's facility and ELS, the Project shall require the services of MGSO in support of test and training. Those services shall consist of interfacing with the DSN, telemetry processing, command generation and data access by the remote science workstations.

8.3.3   Telemetry

The AMMOS shall reconstruct telemetry packets from the DSN transfer-frame synchronized spacecraft telemetry at rates from 10 bps to 85.3 ksps, label the packets with corresponding Spacecraft Event Time and data accountability information, and store the packets. DSN monitor data shall be processed in a similar manner.

MGSO shall have the prime responsibility for Reed-Solomon decoding.

8.3.4   Command

The MGSO shall accept command files from the Project, route them to the DSN, and control and confirm the radiation of the commands to the spacecraft. In addition, MGSO shall provide the tools to enable the Project to develop these commands including those functions residing in the remote science workstations.

8.3.5   Simulation

MGSO shall generate simulated data streams (telemetry, monitor, command) for use by the Project in testing and training. The MGSO shall support short-loop and DSN long-loop simulation starting at GDS integration for spacecraft system test.

Table 8-1. MGSO Support Requirements

DATA SYSTEM DELIVERY	BEGIN: Development	10/01/95
	END: End of Project	04/01/03

Hardware and software capabilities to support Project ground software development and operations as identified in Project and MGSO schedules.

OPERATIONS SUPPORT	BEGIN: GDS Integration	04/01/96
	END: End of Project	04/01/03

4/1/96 to 9/1/96	Approximately 50 hours per week to support: (a) Ground system integration in preparation for flight sequence testing during the spacecraft system test period. (b) Flight sequence and telemetry data flow testing during the spacecraft system test period. (c) Ground system integration for launch and cruise capabilities.
9/1/96 to Launch	Approximately 60 hours per week to support: (a) MOS test and training. (b) Spacecraft compatibility tests at ELS. (c) Launch Tests Twenty-four hour per day access to MSA, remote workstations and Project Data
Launch to 1/1/2000	Support commensurate with DSN tracking coverage defined in Table 3-3. Twenty-four hour per day access to MSA, remote workstations and Project data. Additional support to perform test and training in preparation for encounter capabilities.
1/1/2000 to 4/1/2003	Twenty-four hour per day access to MSA, remote workstations and Project data.

8.3.6   Communications

        The MGSO shall provide data and voice communications between the Project MSA and MGSO. In addition MGSO shall provide as appropriate the communications interface between the Project MSA and the DSN.

8.3.7   Error Rate

        The rate of uncorrectable errors produced by the MGSO in data received or generated by the MGSO shall not exceed 10^{-8}. Data containing known uncorrected errors shall be recorded for later analysis. Additionally, the MGSO shall provide protocols, hardware and software as required to obtain an end-to-end 10^{-8} error rate data transmission to/from remote science users. The rate of packet loss produced by the MGSO shall not exceed $.5x10^{-4}$.

8.3.8   Test and Training

        All MGSO services and capabilities committed to support launch and cruise flight operations shall participate in Project MOS test and training functions to be conducted prior to launch. All MGSO services and capabilities committed to support encounter flight operations shall participate in Project MOS test and training functions to be conducted post launch.

8.3.9   Monitoring Services

        MGSO shall provide the tools and personnel to decommutate the spacecraft engineering telemetry, perform data number-to-engineering units conversion, process the data for alarm monitoring, format and display the data and perform multimission monitoring of the spacecraft health. This service shall include those activities associated with monitoring the telecommunication link and the sending of commands.

8.3.10   Project Interface

        The MGSO shall establish an operational point of contact for the Project and all communication shall be through this control point. MGSO shall perform the services required to receive and transfer data between the Project MSA and the DSN in accordance with DSN/MGSO agreements. The MGSO shall ensure that no data are permanently lost because of a failure in MGSO provided services.

8.3.11   Project Data Base

The MGSO shall perform the functions required to create, manage and control access to the Project data. The data base shall contain: science and engineering telemetry data, radiometric, radio science occultation data, DSN monitor data, planning information including command files, and science, engineering and navigation processed data. MGSO shall ensure that no data are permanently lost because of a data base failure.

The MGSO shall provide an access capability that allows a controlled number of external users to browse the catalog using dial-up and SPAN communication links, 24 hours a day from the beginning of the mapping phase to the end of the project.

8.3.12   Security

The MGSO shall provide security mechanisms that restrict access to or minimize the probability of unauthorized access to the science data. This requirement is applicable to all raw science data received from the spacecraft and retained in a MGSO controlled environment and to reduced data that are designated "restricted access" and that are properly placed in a MGSO controlled environment. The MGSO shall also provide security mechanisms that restrict access to uplink command data by non-authorized users.

8.3.13   Planning/Sequencing Tools

The MGSO shall provide multimission tools which the project can configure or adapt for request generation, sequence integration, constraint checking and resource analysis, command generation, timeline generation, and event scheduling (Sequence of Events generation).

8.3.14   Support Tools

The MGSO shall provide on the workstations, tools for the Project to use in its operations activities. These tools shall include but not be limited to word processor, spread sheet capabilities, library of analysis support software (i.e. plot/display programs, statistical analysis routines, file utilities, mail system) and generation of Project-unique data bases, such as decommutation tables, calibration tables and command translation tables.

The MGSO shall provide on the workstations, the tools for the Project to generate displays from engineering and facility data. It shall provide multimission display formats for use by the Project.

The MGSO shall provide tools from the Navigation Ancillary Information Facility (NAIF) to support the development and use of the SPICE kernels (Spacecraft ephemeris, Planet/satellite ephemeris and constants, Instrument data, C-pointing matrix, Event data) for the Project.

8.3.15   Science Workstations

         The MGSO shall provide and maintain workstations via the MGSO loan pool, including software to support communicating with the Project MSA and its data base, to the science Principal Investigators, Team Leaders and Interdisciplinary Scientists at their home institutions.

8.3.16   Data Products

         The MGSO shall provide the tools and personnel to produce data products, (e.g. Sequence of Events, E Kernel) as negotiated with the Project and to place these products in a data base.

8.3.17   Link Performance

         The MGSO shall provide the tools and personnel to predict and monitor the telecommunications link performance and maintain a telecom link data base. The multimission Flight Control Team as part of the "Monitoring Services" shall monitor link performance and report the results to the Project.

8.3.18   Resource Allocation Plan

         The MGSO shall provide a ground data system resource allocation plan for scheduling the activities identified in Table 3-2.

8.3.19   Data Return

         The MGSO shall capture and transfer to the project data base 99% of the science data provided by the DSN during the mapping phase.

9.0   SECTION 9 REQUIREMENTS ON JPL SPACE COUNCIL

        This section documents the requirements on the JPL Space Council from each of the three elements of the mission system (mission design, navigation design, and mission operations design).

9.1   JPL SPACE COUNCIL REQUIREMENTS FROM MISSION DESIGN

        No Requirements

9.2   JPL SPACE COUNCIL REQUIREMENTS FROM NAVIGATION DESIGN

        No Requirements

9.3   JPL SPACE COUNCIL REQUIREMENTS FROM MISSION OPERATIONS DESIGN

9.3.1   Project Operations Support Area

        The Space Council shall provide 7683 net sq. ft. of facility space to the Project for its Project office and its Project Operations Area (POSA).

10.0   SECTION 10 REQUIREMENTS TRACEABILITY AND RATIONALE

3.1.1	Launch Opportunity	Project	Direction from NASA.
3.1.2	Launch Vehicle	Project	Direction from NASA.
3.1.3	Launch Period	Project	Twenty days is believed to be adequate launch period for Delta 7925. Targeting additional days will increase chance of getting launched if spacecraft and operations can support these days.
3.1.4	NASA Planetary Protection	Project	NASA Policy.
3.1.5	Cruise and Orbit Insertion Phase Science	Project	To minimize cost and risk.
3.1.5.x	Science Calibrations and Observations	Science	Provides engineering checkout, unique science and Mars atmosphere knowledge for aerobraking operations.
3.1.6	Mapping Orbit Design	Science	Best orbit for meeting geoscience and climatology objectives. Provides sun synchronous frozen orbit with a repeatable ground track.
3.1.7	Gravity Calibration Period	Navigation	Better navigation capability (gravity field knowledge) at the beginning of the mapping phase.
3.1.8	Spacecraft and Instrument Checkout Period	Project	Ten days is estimated time needed to configure and checkout the spacecraft before committing to science data collection.
3.1.9	Mapping Phase Commencement	Derived by Mission Design	Simplifies mission planning.
3.1.10	Mapping Phase	Project	Direction from NASA (one Mars year, 687 Earth days). Allows for seasonal geoscience and climatology observations.
3.1.11	Relay Phase	Project	Direction from NASA to support Mars International Exploration Program.
3.1.12	Science Data Return	Project	Provide continuous science collection (record/playback). Additionally provide for high-rate real-time return every third day.
3.1.13	Radio Science Data	Project	Earth occultations provide unique opportunities for radio science.

3.1.14	Solar Conjunction Command Moratorium	Derived by Mission Design	Avoid spacecraft maneuvers and commanding when commanding may be impaired.
3.1.15	DSN Usage	Project	Constrained data return policy due to shared resource.
3.1.16	Maneuver Constraints		
3.1.16.1	Trajectory Correction Maneuver	Mission Operations	Minimum time required to prepare for first TCM. Minimize planned spacecraft activities during critical pre-MOI time period.
3.1.16.2	Maneuver Interval	Mission Operations	Ten days is minimum time required to routinely prepare for maneuvers, with the exception of aerobraking maneuvers for which the minimum time is 24 hours.
3.1.16.3	Sun Safe Maneuver Direction	Science	MOC and MOLA can be damaged by sunlight.
3.1.17	Aerobraking	Project	Delta V constraints make aerobraking likely to achieve desired mapping orbit.
3.1.18	Avoidance of Spacecraft Overheating During Capture	Derived by Mission Design	Obvious. Altitude for overheating based on worst case atmosphere during peak of solar cycle. Assumes overheating occurs when heating rate equals solar rate at 1 A.U. (135 mW/cm^2). Assumes hyperbolic approach velocity of 3.0 km/s.
3.2.1	Mission Delta-V Allocations	Derived by Mission Design and Navigation	Allocated delta V is consistent with spacecraft performance (mass, Isp, and propellant) requirements.
3.2.2	Avoidance of Spacecraft Overheating During Capture	Derived by Mission Design	Obvious. Altitude for overheating based on worst case atmosphere during peak of solar cycle. Assumes overheating occurs when heating rate equals solar rate at 1 A.U. (135 mW/cm^2). Assumes hyperbolic approach velocity of 3.0 km/s.
3.2.3	Planetary Protection	Project	NASA policy.
3.2.4	Mapping Orbit Specification	Derived by Mission Design	Optimum orbit for conducting science investigations. Provides sun synchronous frozen orbit with a repeatable ground track.
3.2.5	Mapping Orbit Maintenance	Derived by Mission Design	Provides appropriate bounds to maintain the sun synchronous frozen orbit with a repeatable ground track.

3.2.5.1	Node	Derived by Mission Design	Provides appropriate bounds to maintain the sun synchronous frozen orbit with a repeatable ground track.
3.2.5.2	Semi-Major Axis	Derived by Mission Design	Provides appropriate bounds to maintain the sun synchronous frozen orbit with a repeatable ground track.
3.2.5.3	Eccentricity	Derived by Mission Design	Provides appropriate bounds to maintain the sun synchronous frozen orbit with a repeatable ground track.
3.2.6	Mapping Orbit Prediction - 14 days	Science	Permits science teams to prepare instrument commands tailored to Mars surface features.
3.2.7	Orbit Reconstruction During Mapping Phase	Science	Needed for science data analysis.
3.2.8	Orbit Insertion Phase Maneuver Frequency	Derived by Mission Design	Needed to ensure attainment of final 2:00 PM mapping orbit.
3.2.9	OTM Frequency	Derived by Mission Design and Navigation	Required to maintain orbit within the appropriate bounds.
3.2.10	Aerobraking Phase Orbital Accuracy		Required to support the implementation of aerobraking to achieve the final mapping orbit.
3.3.1	Institutional Support	Project	Reduce operating costs compared to previous missions.
3.3.2	Data Acquisition	Derived by Mission Operations	Contain operating costs; increase probability of returning acquired data by minimizing operating complexity associated with different data rates and modes.
3.3.2.1	Data Constraints	Mission Design	High confidence of returning science data while meeting project policy on DSN usage.
3.3.2.2	DSN Constraints	Mission Design and Navigation	Tracking coverage requirements developed by Mission Design and documented in Mission Requirements Request (MRR).
3.3.3	Mission Critical Failures	Project	Avoid all mission critical failures.
3.3.3.1	Operational Errors	Project	Reduce risk to an acceptable level; contain operating costs.

3.3.3.2	Ground Equipment Failure	Project	Reduce risk to an acceptable level; contain development and operating costs. (For example, having to radiate a ground command to the spacecraft at a specific time.)
3.3.3.3	Project Supplemental Support	Project	Reduce risk to an acceptable level; contain operating costs.
3.3.4	Degraded Operation	Project	Contain development costs while providing work around in case of failures.
3.3.5	Data Base / Data Records	Project and Science	Meet science and flight operations requirements.
3.3.5.1	Project Data Base	Project	Facilitate project data exchange.
3.3.5.2	Archival Data Transfer	Science	For long term science data retention.
3.3.6	Telescience	Derived by Mission Operations	Reduce operations costs related to a long duration mission with constant activity; incorporate the mission characteristics (repetitive mapping) to reduce operating costs; respond to the science community of having more direct control of their investigations on a daily basis.
3.3.6.1	Distributed Data System	Derived by Mission Operations	Provide science leader control of his investigation from his home institution.
3.3.6.2	Support Priority	Derived by Mission Operations	Task prioritization may be necessary if data system becomes overloaded.
3.3.6.3	Data Delivery Time	Derived by Mission Operations	Timely deliver of science data within capability of operations system.
3.3.7	Data Return	Project	Lower development and operating costs; multiple opportunities to obtain science data; significant development costs to guarantee achieving the last few percent; experience indicates that higher return can be achieved without having to design for it.
3.3.8	Flight Sequence Process	Derived by Mission Operations	Reduces risk and operating costs.
3.3.8.1	Sequence Development	Project	Reduce risk to an acceptable level; contain development and operating costs.

3.3.8.2	Sequence Implementation Cycle	Derived by Mission Operations	Reduces risk and operating costs.
3.3.8.3	Sequence Verification and Validation	Derived by Mission Operations	Reduce risk
3.3.9	Command Process	Derived by Mission Operations	Provides MOS with a near real-time commanding capability to support sequence loads, flight software loads and emergency commanding.
3.3.9.1	Command Verification and Validation	Derived by Mission Operations	Reduces risk.
3.3.9.2	Science Non-Interactive	Derived by Mission Operations	Provides science investigators with an expeditious command process to handle non-interactive science command requests.
3.3.10	Flight Sequence Adaptability		
3.3.10.1	Flight Sequence Change Control Process	Derived by Mission Operations	Reduces risk.
3.3.10.2	Changes to Onboard Sequences	Derived by Mission Operations	Contains operations costs and reduces risk.
3.3.11	Flight Software Reprogramming	Derived by Mission Operations	Contains operations costs.
3.3.12	Project Staffing Period	Project	Contain operations costs.
3.3.13	Maneuvers	Mission Design	Maneuver frequencies necessary to accomplish mission.
3.3.14	Ephemerides		
3.3.14.1	Planetary Ephemeris	Derived by Mission Operations	Communications with spacecraft requires on-board planetary ephemeris.
3.3.14.2	Spacecraft Ephemeris for Nadir Pointing	Spacecraft	Spacecraft orbit ephemeris required to maintain nadir pointing attitude in the event of loss of the horizon sensor.

4.1.1	DSN Coverage	Mission Design and Navigation	Tracking coverage requirements based on data collection requirements and navigation needs, within project policy on DSN usage.
4.1.2	DSN Lockup Time	Mission Design	Lockup constraint needed to minimize playback time losses on multiple orbits on a tracking pass.
4.2.1	Tracking Data Acquisition Requirements	Navigation	Provide navigation data necessary to accomplish mission requirements as specified in Section 3.2.
4.2.2	Tracking Data Accuracy and Calibrations	Navigation	Provide necessary navigation data quality to accomplish mission requirements as specified in Section 3.2.
4.2.3	DSN Tracking Station Coordinates and Accuracy	Navigation	Necessary to support Orbit Determination function for requirements in Section 3.2
4.2.4	Data Conditioning and Data Delivery	Navigation	To satisfy requirements in Section 3.2.
4.2.4.1	Radiometric Data Delivery Schedule	Navigation	To satisfy requirements in Section 3.2.
4.3.1	General	Project	Communication with spacecraft
4.3.2	Facility Use	Project / Mission Design	For control of spacecraft and return of science, engineering, and navigation data.
4.3.3	Telemetry	Project	Science and engineering data return.
4.3.4	Command	Project	Compatibility with spacecraft
4.3.5	Simulation	Mission Operations	To checkout ground data system and support personnel training.
4.3.6	Communications	Mission Operations	To coordinate activities, provide command requests, evaluate instrument health, and transfer data.
4.3.7	Error Rate	Mission Operations	To maintain data quality.
4.3.8	Test and Training	Mission Operations	To support training of operations personnel.
4.3.9	Monitoring Services	Mission Operations	Necessary for conduct of mission. Consistent with project approach to lower operations cost.
4.3.10	Project Interface	Mission Operations	Reduces likelihood of misunderstanding between project and DSN.

4.3.11	DSN Monitor Data	Mission Operations	Aids conduct of mission.
4.3.12	Spacecraft Acquisition	Mission Operations	Initial acquisition range to 40,000 km necessary in certain anomaly situations given 30 minute lockup time. Pass acquisition/reacquisition times necessary to support mission activities.
4.3.13	Data Return	Project	Lower development and operating costs; multiple opportunities to obtain science data; significant development costs to guarantee achieving the last few percent; experience indicates that higher return can be achieved without having to design for it.
5.1.1	Injection Energy	Mission Design	Launch energy requirements follow from trajectory optimization, mass requirement derived from expected Delta 7925 capability and spacecraft mass needs.
5.1.2	Probability of Cmd Shutdown	Mission Design	Probability requirement driven by additional s/c propellant needed if fuel depletion shutdown occurs.
5.1.3	Launch Period Duration	Mission Design	Follows from Project Policy. Provides high probability of launching in 1996 opportunity.
5.1.4	Daily Launch Windows	Mission Design	Needed to ensure .99 probability of launch.
5.1.5	Spacecraft Attitude Constraint	Science	Damage to the Mars Observer Camera will occur if the sun falls within of its boresite which is along the spacecraft +Z axis.
5.1.6	Collision and Contamination Avoidance	Mission Design	Avoid spacecraft contamination and collision.
5.2.1	Injection Accuracy	Mission Design / Navigation	FOM is consistent with TCM delta V requirement on spacecraft.
5.2.2	Injection-Error Covariance	Navigation	Needed to compute TCM delta V requirement.
5.2.3	Injection State	Navigation	Needed for DSN initial acquisition trajectory prediction and for computing initial post-injection trajectory.
6.1.1	Lifetime	Mission Design	Lifetime to complete mapping phase and accomplish quarantine maneuver.

6.1.2	Launch Period	Mission Design	Follows from 3.1.3.
6.1.3	Launch Mass	Mission Design	Launch mass within requirement on launch vehicle. GFP and propellant masses are necessary to accomplish mission and are negotiated values.
6.1.4	Total Delta-V	Mission Design and Navigation	Spacecraft velocity change requirement necessary to accomplish mission with 99th percentile probability.
6.1.5	Cruise Phase Maneuvers	Mission Design	Spacecraft compatibility with cruise phase maneuvers necessary to accomplish mission.
6.1.6	Orbit Insertion Maneuvers	Mission Design and Navigation	Spacecraft compatibility with JPL orbit insertion strategy.
6.1.7	Planetary Protection	Mission Design	Any part of the spacecraft separated after TCM-1 could violate Planetary Protection requirements. This is prohibited to avoid further complicated Planetary Protection analyses.
6.1.8	Mapping Orbit Domain	Mission Design	Spacecraft compatibility with mapping orbits between 378 and 400 km.
6.1.9	Orbit Trim Maneuvers	Mission Design and Navigation	Spacecraft compatibility with orbit maintenance strategy, requiring maneuvers up to every 7 days.
6.1.10	Mapping Attitude Orbit Reference	Mission Design	Defines nadir pointing attitude and orbital coordinate system.
6.1.11	Solar Conjunction	Mission Design	Spacecraft must survive without ground commands during solar conjunctions.
6.1.12	Uplink	Mission Design	X-band uplink required, must permit spacecraft commanding simultaneous with navigation data types - Doppler and ranging.
6.1.13	Command Rates	Mission Design	Provide normal commanding rate and a lower rate for emergency commanding.
6.1.14	Emergency Uplink	Mission Design	Minimum commanding rate required for emergency commanding.
6.1.15	Downlink	Mission Design	X-band downlink required.

6.1.16	Cruise and Orbit Insertion Downlink	Mission Design	Data return capability during cruise and orbit insertion phases based on minimum engineering.
6.1.17	Mapping Phase Downlink	Mission Design	Provide sufficient downlink signal to return 18.6 kbps playback rate to 34m (HEF) DSS.
6.1.18	Mapping Phase Science Data Return	Mission Design	Minimum data return requirements for recorded data and real-time data.
6.1.18.1	Recorded Science Data Return	Mission Design	Follows from 3.1.16.
6.1.18.2	Real-Time Science Data Return	Mission Design	Follows from 3.1.16.
6.1.19	Data Rates	Mission Design	Provide PDS-compatible data rates for recording, playback, and real-time data return.
6.1.20	Data Streams	Mission Design	Follows from 3.1.16.
6.1.21	Data System Modes	Mission Design	Provide data system modes for collection and return of recorded and real-time science and engineering data and engineering-only data.
6.1.22	Data Storage Capability	Mission Design	Sufficient recorder capability is required to permit flexibility in DSN scheduling to allow playback of data, recorded continuously at up to 14 kbps.
6.2.1	Tracking Data	Navigation	Return Navigation data necessary to accomplish mission as specified in Section 3.2.
6.2.2	Antenna Phase Center Motion	Navigation	Provide Doppler accuracy consistent with 6.2.2.
6.2.3	Angular Momentum Desaturation	Navigation	Enables orbit determination accuracies necessary for mission as specified in Section 3.2.
6.2.4	Propulsive Maneuver Execution Errors	Navigation	Necessary for specifying propellant loading requirement.
6.3.1	Launch		

6.3.1.1	Uplink	Derived by Mission Operations	MOS does not have control of spacecraft until after launch sequence is complete. Provides clean separation of responsibilities.
6.3.1.2	Downlink	DSN	DSN required to lock-up within 30 minutes of receipt of signal. Acquisition aid antenna has capability up to 30000 km range for transmission rate of 2000 bps and 40000 km for 10 bps.
6.3.2	Autonomous Operation	Derived by Mission Operations	Reduces the need for continuous tracking to insure spacecraft safety.
6.3.2.1	Autonomous Safing	Derived by Mission Operations	Provides safe operation in event of failure during period when spacecraft is not being tracked.
6.3.2.2	Emergency Commands	Derived by Mission Operations	Provide capability to receive over LGA emergency commands from 34-m HEF DSS at maximum range.
6.3.2.3	Emergency Telemetry	Derived by Mission Operations	Provide capability to return emergency engineering telemetry.
6.3.3	Command Requirements	Derived by Mission Operations	Necessary to accomplish mission as defined by Project.
6.3.3.1	Operating Programs	Derived by Mission Operations	Necessary to adjust on-board operating parameters.
6.3.3.2	Stored Sequence Commands	Derived by Mission Operations	Necessary to conduct spacecraft and payload activities.
6.3.3.3	Real Time Commands	Derived by Mission Operations	To achieve balance of capabilities with mission operations resources and to provide backup capabilities.
6.3.3.4	Error Protection	Derived by Mission Operations	Protection against erroneous command.
6.3.3.5	Uplink Frequency	Derived by Mission Operations	Planned uplink frequency necessary to conduct spacecraft and payload activities.
6.3.3.6	Time Critical Commands	Derived by Mission Operations	Protection against unscheduled communication outages.

6.3.3.7	Command Rate Visibility	Derived by Mission Operations	Provides unambiguous indicator of command rate in the event of spacecraft autonomous switching due to fault protection.
6.3.4	Engineering Data Requirements		
6.3.4.1	Health Assessment	Derived by Mission Operations	Health assessment in single DSN pass necessary for rapid response in event of an anomaly.
6.3.4.2	Consumable Status	Derived by Mission Operations	To facilitate mission planning.
6.3.4.3	Memory Contents and Validation	Derived by Mission Operations	To facilitate anomaly investigation, reduce risk, and to contain operating costs.
6.3.4.4	Performance Visibility	Derived by Mission Operations	To facilitate spacecraft health assessment.
6.3.4.5	Command Verification	Derived by Mission Operations	To verify proper functioning of spacecraft.
6.3.4.6	Pointing Reconstruction	Science	To satisfy ID & SRD requirement 3.3.7.
6.3.5	Spacecraft Ephemeris Prediction	Derived by Mission Operations	Contain operating costs.
6.3.6	Data Recorder Management	Derived by Mission Operations	To prevent data loss when occultation interrupts playback.
6.3.7	Spacecraft Clock		
6.3.8	Data Return Percentage	Project	Lower development and operating costs; multiple opportunities to obtain science data; significant development costs to guarantee achieving the last few percent; experience indicates that higher return can be achieved without having to design for it.
6.3.9	Data Standards	Project	Compliance with PD 642-530.
6.3.10	Sequence Test	Derived by Mission Operations	To ensure spacecraft-MOS compatibility.

6.3.11	Autonomous Eclipse Detection and Command Initiation	Derived by Mission Operations	Reduces operational complexity and cost.
6.3.12	Autonomous Equator Crossing Detection and Command Initiation	Science/ Derived by Mission Operations	Provides orbital timing information to the instruments. Autonomous function reduces operational complexity and cost.
7.1.1	Altitude Variation	Mission Design	Instruments must be compatible with expected altitude variations for frozen mapping orbit. Altitude extremes are for a 378.1 index altitude and 0.007 orbit eccentricity. Assumes 3376 km Mars polar radius.
7.1.2	Cruise and Orbit Insertion Science	Project	To minimize cost and risk.
7.3.1	Data Standards	Project	Compliance with CCSDS data standards.
7.3.2	Payload Sequence Capability	Project	Allocate spacecraft resource.
7.3.3	Instrument Health Monitor	Derived by Mission Operations	Reduce operating costs compared to previous missions; responsibility consistent with distributed science operating approach.
7.3.4	Science Analysis	Project	Responsible use of government equipment and resources. Data needs to be returned on a timely basis.
7.3.5	Science Data Archival	Project	Obligation to save data for future research.
8.2.1	Planetary Ephemeris	Navigation	To satisfy requirements in Section 3.2.
8.2.2	Mars Natural Satellite Ephemeris	Navigation	To put satellite ephemeris information in the SPK file as requested by Science.
8.2.3	Computation Support Requirements	Navigation	To satisfy requirements in Section 3.2.
8.2.4	Radiometric Data Storage	Navigation	To satisfy requirements in Section 3.2.
8.3.1	General	Project	Reduce operating costs compared to previous missions, by utilizing institutional resources.
8.3.2	Facility Use	Project	For mission support.
8.3.3	Telemetry	Mission Operations	Functions necessary for processing downlink data.

8.3.4	Command	Mission Operations	Functions necessary to command spacecraft.
8.3.5	Simulation	Mission Operations	To checkout GDS and support personnel training.
8.3.6	Communications	Mission Operations	To coordinate support activities.
8.3.7	Error Rate	Mission Operations	To maintain data quality.
8.3.8	Test and Training	Mission Operations	To support training of operations personnel.
8.3.19	Monitoring Services	Mission Operations	Necessary for conduct of mission consistent with Project approach to lower operations costs.
8.3.10	Project Interfaces	Mission Operations	Reduces likelihood of misunderstanding between project and MGSO.
8.3.11	Project Data Base	Mission Operations	See 3.3.5.1.
8.3.12	Security	Mission Operations	To ensure data are not tampered with.
8.3.13	Planning / Sequencing Tools	Mission Operations	To facilitate sequence planning.
8.3.14	Support Tools	Mission Operations	To facilitate work of operations personnel.
8.3.15	Science Workstations	Mission Operations	To provide investigators the means of interfacing with the project data base.
8.3.16	Data Products	Mission Operations	To facilitate work of operations personnel.
8.3.17	Link Performance	Mission Operations	To facilitate work of operations personnel.
8.3.18	Resource Allocation Plan	Mission Operations	To facilitate DSN scheduling.
8.2.19	Data Return	Mission Operations	Lower development and operating costs; multiple opportunities to obtain science data; significant development costs to guarantee achieving the last few percent; experience indicates that higher return can be achieved without having to design for it.

9.0	Requirements on JPL Space Council		
9.3.1	Mission Support Area	Mission Operations	To facilitate work of operations personnel.

APPENDIX A - Reference Coordinate System

Figure A.1 depicts the nominal alignment of the spacecraft system's body fixed orthogonal (x,y,z) axes with the orbital reference coordinate system in Mars orbit. The fundamental planet reference direction is the nadir direction. The nadir direction is defined by a line passing through the spacecraft perpendicular to the Mars mapping reference spheroid (polar radius = 3375.7 km, equatorial radius = 3393.4 km). The +X axis nominally lies along the direction of the spacecraft velocity vector and is defined to lie in a plane perpendicular to the nadir direction and along the projection of the velocity vector on this plane. The +Y axis also lies in this plane and is orthogonal to both the +Z and +X axes. The +X axis will be close to but not always coincident with the direction of the spacecraft velocity vector, and the +Y axis will be close to but not always coincident with the orbit normal (in the direction of the negative orbit momentum vector). Yaw will be taken to refer to a rotation about the +Z axis, roll will refer to a rotation about the +X axis and pitch will refer to a rotation about the +Y axis.
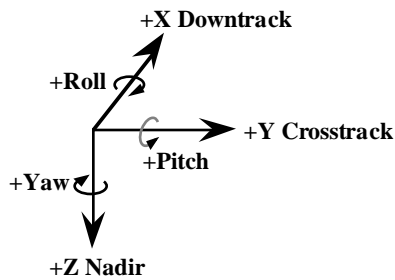
+X Downtrack
+Roll
+Y Crosstrack
+Pitch
+Yaw
+Z Nadir

Figure A.1 - Orbital Reference Coordinate System

APPENDIX B - ACRONYMS

AMMOS	Advanced Multi Mission Operations System
ATDF	Archival Tracking Data Files
AU	Astronomical Unit
BWG	Beam Wave Guide
CCAFS	Cape Canaveral Air Force Station
CCSDS	Consultative Committee for Space Data Standards
CT	Crosstrack
DTF	Development Test Facility
C/CAM	Collision/Contamination Avoidance Maneuver
DE 234	Development Ephemeris No. 234
DSCC	Deep Space Communications Complex
DSN	Deep Space Network
DSS	Deep Space Station
DT	Downtrack
EIRP	Effective isotropic radiated power
ELS	Eastern Launch Site
FOM	Figure of Merit
GDS	Ground Data System
GFP	Government Furnished Property
GSFC	Goddard Space Flight Center
HEF	High Efficiency Antenna
HGA	High Gain Antenna
IAU	International Astronomical Union
IDS	Interdisciplinary Scientist
JPL	Jet Propulsion Laboratory
J2000	(reference epoch for standard astronomical coordinate system)
LAN	Local Area Network
MGDS	Multimission Ground Data System
MGS	Mars Global Surveyor
MIL 71	Merritt Island Station 71
MOI	Mars Orbit Insertion
MOS	Mission Operations System
MGSO	Multimission Ground System Office
MRD	Mission Requirements Document
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications (Network)
NAV	Navigation
NOCC	Network Operations Control Center
ODF	Orbit Data Files
ODP	Orbit Determination Program
OTM	Orbit Trim Maneuver
PAM	Payload Assist Module
PDB	Project Data Base
PDS	Payload Data Subsystem
PI	Principal Investigator
POSA	Project Operations Support Area
RF	Radio Frequency
SEM	Sun Earth Mars
SFDU	Standard Formatted Data Units
SPICE	Spacecraft ephemeris, Planet/satellite ephemeris & constants, Instrument, C-pointing matrix, Event

STL	Spacecraft Test Lab
TCM	Trajectory Correction Maneuver
TDA	Telecommunications & Data Acquisition
TDS	Tracking and Data System
TL	Team Leader